HIGH-CONDUCTIVITY FINSTOCK ALLOY, METHOD OF MANUFACTURE AND RESULTANT PRODUCT

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to aluminum alloy fin material and, more particularly, to an aluminum alloy finstock for brazed heat exchangers having a desirable combination of post-braze strength, thermal conductivity and self-corrosion resistance. The invention also relates to fins made from the finstock and to brazed heat exchangers employing the finstock. The invention further relates to a method of manufacturing the finstock.

Background Information

Heat exchangers, such as, for example, the brazed aluminum alloy automobile radiator 2 shown in Figure 1, typically include a plurality of cooling fins 4 disposed between a plurality of flat fluid-carrying tubes 6. The ends of the fluid-carrying tubes 6 are open to a header plate 8 and a tank 10 (one end of the tubes 6, one header plate 8 and one tank 10 are shown in Figure 1). Coolant is circulated from the tank 10, through the fluid-carrying tubes 6 and into another tank (not shown). The cooling fins 4 transfer heat away from the fluid-carrying tubes 6, in order to facilitate a heat exchange thereby cooling the fluid therein. The cooled fluid is then recirculated through the closed loop circuit of which the radiator is one component.

The fin material or finstock for brazed heat exchangers is typically fabricated from 3XXX series aluminum alloys such as, for example, AA3003 or AA3003+Zn. After brazing, these alloys are characterized by a fairly low thermal conductivity (as measured by electrical conductivity) because of high levels of Mn trapped in solid solution. This has become increasingly problematic as heat exchanger fabricators continually endeavor to reduce the weight of heat exchanger components by, for example, down-gauging the fluid-carrying tubes 6 and cooling fins 4. The thermal conductivity of the cooling fins 4 directly impacts the efficiency of the heat exchanger. The cooling fins 4 need to effectively conduct heat away from the fluid-carrying tubes 6 in order to cool the fluid therein.

Accordingly, if the efficiency and lifetime of heat exchanger components are not to be compromised, down-gauging the cooling fins 4 requires an appropriate increase in thermal conductivity, while still maintaining an effective minimum level of post-braze strength and self-corrosion resistance.

Through experimenting with variations in aluminum finstock alloying compositions and methods of manufacturing, several known attempts have been made to satisfy the increasingly stringent size and weight demands for heat exchangers in, for example, the automotive industry.

U.S. Patent No. 6,165,291 (*Jin et al.*) discloses a process of producing aluminum fin alloy having a tailored corrosion potential and high conductivity. The fin alloy composition restricts Mn to a maximum of 0.6%.

U.S. Patent No. 6,620,265 (*Kawahara et al.*) discloses a method for manufacturing an aluminum alloy fin material for brazing in which the Fe content in the alloy is limited to a maximum of 2.0%.

There is, therefore, a need to provide a lightweight, reduced-gauge aluminum alloy finstock exhibiting a desirable combination of post-braze strength, thermal conductivity and self-corrosion resistance, and a need for a method of manufacturing such finstock.

There is room for improvement in the art of aluminum alloy finstock for brazed heat exchangers and for methods of manufacturing finstock for brazed heat exchangers.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an aluminum alloy finstock having a desirable combination of post-braze strength, thermal conductivity and self-corrosion resistance. This combination of properties is such that it will permit down-gauging of the fin for use in, for example, automotive heat exchangers, such as, for example, radiators, without negatively impacting the performance or service lifetime of the heat exchanger.

It is a further object of this invention to provide a method of manufacturing finstock having the foregoing qualities.

It is another object of the present invention to improve the thermal conductivity of finstock containing Si, Fe, Mn, and Zn, while achieving sufficient post-braze strength, self-corrosion resistance and thermal conductivity.

It is yet another object of the present invention to provide a method of manufacturing the foregoing improved aluminum alloy finstock through a continuous casting process using careful selection and control of casting parameters, such as, for example, molten metal temperature, casting speed, cast gauge, cooling rate and position of the casting machine feeding tip, in order to substantially avoid the formation of coarse intermetallics or clusters of intermetallics in the form of center-line segregation.

It is another object of the present invention to employ specific combinations of rolling reductions and annealing steps, after casting, in order to create the foregoing desirable combination of product attributes.

It is a further object of this invention to provide a fin made from the foregoing finstock.

It is yet another object of the present invention to provide a brazed aluminum heat exchanger having fins made from the foregoing finstock.

These needs and others are satisfied by the present invention, which provides an aluminum alloy finstock having a desirable combination of, among other things, lightweight, post-braze strength, thermal conductivity and corrosion resistance. The invention also provides a newly discovered method of manufacturing such finstock through continuous casting with a careful selection and control of casting parameters, such as, for example, molten metal temperature, cooling rate, casting speed, cast gauge and position of the casting machine feeding tip, and then processing the cast strip with specific combinations of cold rolling reductions and annealing steps.

All percentages employed herein, unless otherwise specified, are weight-percent. The term "up to about," as employed herein, explicitly includes, but is not limited to, the possibility of zero weight-percent of the particular alloying component to which it refers. For example, up to about 0.05% In may include an alloy having no In.

As one embodiment of the invention, a finstock comprises: an aluminum alloy preferably comprised of about 0.7-1.2% Si, more preferably about 0.8-1.1% Si, about 1.9-2.4% Fe, more preferably about 2.0-2.2% Fe, about 0.6-1.0% Mn, more preferably about 0.6-0.8% Mn, up to about 0.5% Mg, more preferably up to about 0.2% Mg, up to about 2.5% Zn, more preferably up to about 1.5% Zn, up to about 0.10% Ti, more preferably up to about 0.05% Ti, and up to about 0.05% In, more preferably up to about 0.03% In, with the remainder comprising Al and tolerable impurities.

Any incidental elements or tolerable impurities are preferably comprised from the following: up to about 0.2% Cu, more preferably up to about 0.05% Cu, up to about 0.2% Zr, more preferably up to about 0.05% Zr, up to about 0.05% Cr and up to about 0.3% Ni, more preferably up to about 0.05% Ni, with the aggregate of all tolerable impurities preferably not to exceed about 0.4% and more preferably not to exceed about 0.10%.

The foregoing finstock preferably exhibits a post-braze electrical conductivity of greater than about 48%IACS, and more preferably greater than about 50%IACS, and a post-braze ultimate tensile strength (UTS) preferably greater than about 120MPa, and more preferably greater than about 130MPa.

As another embodiment of the invention, a fin for a heat exchanger, such as, for example, a brazed aluminum automobile radiator is formed from an aluminum alloy finstock preferably comprised of about 0.7-1.2% Si, more preferably about 0.8-1.1% Si, about 1.9-2.4% Fe, more preferably about 2.0-2.2% Fe, about 0.6-1.0% Mn, more preferably about 0.6-0.8% Mn, up to about 0.5% Mg, more preferably up to about 0.2% Mg, up to about 2.5% Zn, more preferably up to about 1.5% Zn, up to about 0.10% Ti, more preferably up to about 0.05% Ti, and up to about 0.05% In, more preferably up to about 0.03% In, with the remainder comprising Al and tolerable impurities.

Any incidental elements or tolerable impurities in the foregoing fin are preferably comprised from the following: up to about 0.2% Cu, more preferably up to about 0.05% Cu, up to about 0.2% Zr, more preferably up to about 0.05% Zr, up to about 0.05% Cr and up to about 0.3% Ni, more preferably up to about 0.05% Ni, with

the aggregate of all tolerable impurities preferably not to exceed about 0.4% and more preferably not to exceed about 0.10%.

As another embodiment of the present invention, a brazed aluminum heat exchanger comprises: at least one tank structured to hold a coolant; a header plate coupled to the at least one tank, the header plate including a plurality of apertures for receiving a plurality of substantially parallel fluid-carrying tubes each extending substantially perpendicular from one of the plurality of apertures in the header plate and structured to receive the coolant therethrough; and a plurality of fins disposed between the plurality of fluid-carrying tubes, the fins being in thermal communication with the plurality of fluid-carrying tubes and structured to transfer heat away therefrom, in order to cool the fluid as it circulates therein. The plurality of fins being formed from an aluminum alloy finstock preferably comprised of about 0.7-1.2% Si, more preferably about 0.8-1.1% Si, about 1.9-2.4% Fe, more preferably about 2.0-2.2% Fe, about 0.6-1.0% Mn, more preferably about 0.6-0.8% Mn, up to about 0.5% Mg, more preferably up to about 0.2% Mg, up to about 2.5% Zn, more preferably up to about 1.5% Zn, up to about 0.10% Ti, more preferably up to about 0.05% Ti, and up to about 0.05% In, more preferably up to about 0.03% In, with the remainder comprising Al and tolerable impurities.

As another embodiment of the present invention, a method of manufacturing aluminum alloy finstock from an alloy preferably comprised of about 0.7-1.2% Si, more preferably about 0.8-1.1% Si, about 1.9-2.4% Fe, more preferably about 2.0-2.2% Fe, about 0.6-1.0% Mn, more preferably about 0.6-0.8% Mn, up to about 0.5% Mg, more preferably up to about 0.2% Mg, up to about 2.5% Zn, more preferably up to about 1.5% Zn, up to about 0.10% Ti, more preferably up to about 0.05% Ti, and up to about 0.05% In, more preferably up to about 0.03% In, with the remainder comprising Al and tolerable impurities, comprises the steps of: casting the alloy as a strip with a preferable thickness of about 2-10 mm, more preferably about 5-9 mm, by controlled continuous strip casting with an average cooling rate above about 300°C/sec. while substantially avoiding temperatures in the molten metal transfer and feeding system that would permit intermetallics to nucleate prior to the molten metal exiting the caster tip and while substantially eliminating the formation of coarse eutectic center-line segregation; cold rolling the strip in one or more passes

to a first intermediate annealing gauge of about 1-4mm; applying a first intermediate anneal to the strip for about 1-10 hours at a temperature of about 300-450°C, more preferably about 1-6 hours at a temperature of about 330-400°C; cold rolling the strip to a final intermediate anneal gauge of about 0.05-0.2mm; applying a final intermediate anneal to the strip for about 1-10 hours at a temperature of preferably about 300-450°C, more preferably about 1-6 hours at a temperature of about 330-400°C; and cold rolling the strip to a final gauge using a preferable reduction of about 15-50%, more preferably about 15-35%.

The method of manufacture may further include the steps of at least one additional intermediate anneal, after the step of applying the first intermediate anneal and subsequently imparting some further cold reduction to the strip after such first intermediate anneal, but before the step of cold rolling the strip to a final intermediate anneal gauge. For example, the strip may be cold rolled to a second intermediate anneal gauge using a reduction of at least about 70% after the first intermediate anneal, annealed for 1-10 hours at a temperature of about 300-450°C, more preferably for 1-6 hours at a temperature of about 330-400°C, then cold rolled again using a reduction of at least 70% to the final intermediate anneal gauge, followed by a final intermediate anneal for about 1-6 hours at a temperature preferably about 300-450°C and more preferably about 330-400°C, and then cold rolled to final gauge.

As another option in the fabrication sequence, a final partial anneal, known as a back-anneal, can be performed on the final gauge material. One potential purpose for this back-anneal might be to impart more workability to the finstock. This optional final back-anneal preferably involves heating the coil for about 1-12 hours at a temperature of about 150- 240°C.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the invention can be gained from the following description of the preferred embodiments when read in conjunction with the accompanying drawings in which:

Figure 1 is an isometric view of a portion of a brazed heat exchanger.

Figure 2 is a flow chart illustrating the steps of a process for manufacturing finstock in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It has been discovered that the finstock and resultant products, such as, for example, heat exchanger fins and brazed heat exchangers, produced in accordance with the method of manufacture of the present invention, exhibit a desirable combination of post-braze strength, thermal conductivity and self-corrosion resistance that is unmatched by conventional finstock materials currently used in brazed aluminum heat exchangers.

Brazed aluminum heat exchangers, such as, for example, automobile radiators 2, as shown in Figure 1, are subject to increasingly stringent size and weight demands as automobile manufacturers endeavor to reduce the weight of the vehicles they produce. The most common way to reduce the weight of such heat exchangers is to reduce the size of their components, including reducing the gauge and therefore the weight of the heat exchanger cooling fins 4. However, it is well known in the art that down-gauging the fins 4 results in reduced heat carrying capacity and therefore reduced heat exchanger efficiency. Accordingly, if the efficiency and lifetime of the heat exchanger is not to be compromised, down-gauging the fin 4 requires an appropriate increase in thermal conductivity while maintaining a sufficient level of post-braze strength and self-corrosion resistance.

It has been discovered in the present invention that, through careful selection of the finstock alloy composition and controlling the method of manufacture including the casting method, casting parameters and subsequent fabrication process, a finstock exhibiting these desired enhanced post-braze characteristics can be produced. As shown in Figure 1, cooling fins 4 and brazed aluminum heat exchangers 2 employing a plurality of cooling fins 4 made from such finstock, likewise exhibit the foregoing desirable characteristics.

As shown in Figure 1, a brazed aluminum heat exchanger 2 in accordance with the present invention includes a plurality of fluid-carrying tubes 6. The ends of the fluid-carrying tubes 6 are open to a header plate 8 and a tank 10 (one end of the fluid-carrying tubes 6, one header plate 8 and one tank 10 are shown in Figure 1). Coolant is circulated from the tank 10, through the fluid-carrying tubes 6 and into another tank (not shown). As shown, a plurality of cooling fins 4, made from the following exemplary finstock, are disposed between the fluid-carrying tubes 6, in

order to transfer heat away therefrom thereby facilitating a heat exchange cooling the fluid therein.

The composition of the exemplary finstock alloy preferably comprises between about 0.7-1.2% Si, more preferably between about 0.8-1.1% Si, between about 1.9-2.4% Fe, more preferably between about 2.0-2.2% Fe, between about 0.6-1.0% Mn, more preferably between about 0.6-0.8% Mn, up to about 0.5% Mg, more preferably up to about 0.2% Mg, up to about 2.5% Zn, more preferably up to about 1.5% Zn, up to about 0.10% Ti, more preferably up to about 0.05% Ti, and up to about 0.05% In, more preferably up to about 0.03% In, with the remainder comprising Al and tolerable impurities.

Incidental elements or tolerable impurities in the finstock are preferably comprised from the following: up to about 0.2% Cu, more preferably up to about 0.05% Cu, up to about 0.2% Zr, more preferably up to about 0.05% Zr, up to about 0.05% Cr and up to about 0.3% Ni, more preferably up to about 0.05% Ni, with the aggregate of all tolerable impurities preferably not to exceed about 0.4% and more preferably not to exceed about 0.10%.

The purpose for using each of the aforementioned alloying components in the exemplary finstock, and the reasons for limiting the content of each therein, will now be discussed.

Silicon contributes to both particle and solid solution strengthening. An insufficient Si content, for example, less than about 0.7%, results in reduced strengthening while too much Si, for example, more than about 1.2%, results in decreased thermal conductivity and a reduced melting temperature undesirably effecting the heat exchanger during the brazing operations.

Iron in the alloy forms relatively small intermetallic particles during casting, that contribute to particle strengthening. Less than about 1.9% Fe does not take full advantage of the strengthening effect, while Fe in excess of about 2.4% results in the formation of large primary intermetallic particles which inhibit the ability to cold roll the alloy to the desired final gauge. Fe has very low solubility in aluminum, so its influence on conductivity is relatively small. Iron in the range of about 2.0 - 2.2% is a good compromise for balancing post-braze strength and ease of manufacture.

Manganese contributes to solid solution strengthening and particle strengthening of the finstock. However, it is well known that Mn in solid solution has a negative impact on conductivity. It has been discovered in the present invention, that in alloys with high Fe and Si content, such as the exemplary finstock, Mn levels of about 0.6-1.0% can be beneficial for strengthening and self corrosion resistance without a significant negative impact on conductivity. The preferred range of about 0.6-0.8% Mn provides the best balance of conductivity with the other product attributes.

Magnesium improves the post-braze strength of the cooling fin and for that reason, Mg levels of up to about 0.5% are acceptable and beneficial for strengthening. However, to avoid adversely affecting brazeability, for example, by impeding the ability for brazing with conventional CAB brazing fluxes, such as, for example, NOCOLOK® flux produced by *Solvay Fluorides Incorporated* of 5010 North Skiatook Road, Catoosa, Oklahoma, the Mg level is preferably kept low, preferably less than about 0.2%.

Zinc affects the corrosion potential of the finstock. By reducing the corrosion potential of the finstock, Zn has the effect of causing the fins to function as sacrificial anodes, thereby providing corrosion protection for the tubes of the heat exchanger to which they are brazed. Zinc has a detectable, but relatively small effect on strength and thermal conductivity. For this reason the minimum amount of Zn required for cathodic protection of the tube is added. Usually that will require at least about 0.3% Zn. More than about 1.5% Zn will have an impact on conductivity and self-corrosion rate. However, in some instances, higher Zn contents of, for example, up to about 2.5% Zn might be desirable at the expense of conductivity and self-corrosion properties.

Indium in the finstock functions similarly to Zn, serving to lower the corrosion potential of the finstock and thus provide a sacrificial anode effect. When used in conjunction with, or in place of Zn, In can fulfill the same function as Zn. However, for cost and scrap loop reasons, In is less desirable than Zn. When In is used it should be at levels of less than about 0.05% and most benefit will be obtained by keeping In content less than about 0.03%.

Titanium, can be used as a grain refining additive during casting to aid the casting process and to help minimize centerline segregation. However, Ti in solid solution has a negative impact on conductivity. Therefore, only the minimum amount needed for grain refinement is employed. This is preferably less than about 0.10% and more preferably less than about 0.05%.

Cu can enhance the post braze strength of the fin material, however, it can have a detrimental influence on the corrosion potential of the fin and also on fin self-corrosion characteristics. For that reason, while up to about 0.2% can be added for strength, Cu content is preferably kept at levels below about 0.05%.

Zirconium can be added to fin alloys to help control the post-braze grain size and shape. For that reason up to about 0.2% Zr might be incorporated in the invention finstock alloys. However, it has been discovered that control of the grain structure is relatively easy in these alloys. Accordingly, Zr is not generally needed, and levels of less than about 0.05% are preferred.

Cr may perhaps add a small amount of strength. However, Cr is known to reduce conductivity. Therefore, Cr content should preferably be kept below about 0.05%.

Ni has been shown to promote strength without a significant detrimental influence on conductivity. It is known, however, to have a negative impact on self-corrosion characteristics of the fin. It is envisioned that up to, for example, about 0.3%Ni might be tolerated in some specific instances, however, in general, Ni should be kept to less than about 0.05%.

In addition to careful selection of the alloy composition itself, the present invention also relies on precise selection of the continuous casting parameters suitable for producing re-roll useful for fabrication of finstock from the exemplary alloy composition. Such parameters include, for example, molten metal temperature, cooling rate, casting speed, casting gauge and position of the casting machine feeding tip. For example, casting needs to be performed in such a manner as to produce an alloy strip substantially without coarse intermetallics, such as, for example, primary Fe-bearing intermetallics and without heavy bands of eutectic segregation in the form of center-line segregation.

As discussed in U.S. Patent No. 6,620,265, it would be expected that a cast stock having the exemplary alloy composition would result in unacceptable fabrication characteristics, such as, for example, strip breaks during cold rolling, due to, for example, primary Fe-bearing particles. In addition U.S. Patent No. 6,620,265 indicates that a finstock in accordance with the present invention would exhibit excessive droop during a brazing thermal cycle, would have unacceptable self-corrosion characteristic, and would exhibit melting during brazing. However, it has been discovered that careful selection and control of casting conditions and employing the method of manufacture in accordance with the present invention, overcomes such problems and allows for the production of finstock with highly desirable combinations of, among other things, post-braze strength, thermal conductivity and corrosion resistance.

As illustrated in Figure 2, the exemplary finstock is fabricated using a method of manufacture, including a first step of continuously casting the exemplary alloy into a strip 11. The exemplary strip is preferably twin-roll cast using any known or suitable twin-roll casting machine which, with appropriate selection of casting conditions and caster roll release agent, will provide the requisite minimum cooling rate during freezing. The preferred minimum cooling rate is about 300°C/sec. As shown, the resultant finstock is fabricated from this twin-roll cast strip by multiple pass cold rolling (see, for example, step 12, optional step 13A, step 14 and step 16) and using one or more intermediate partial anneals (see, for example, step 13, optional step 13B and step 15), and an optional final partial anneal (see step 16A).

The exemplary method of manufacture, as illustrated in Figure 2, begins with a step of casting the exemplary alloy as a strip 11 with a preferable thickness of about 2-10mm, more preferably about 5-9mm. The exemplary strip is continuously cast while carefully controlling the molten metal temperature from the furnace to the caster. For ease of illustration, the furnace and caster have not been shown.

Depending upon the specific composition of the alloy, controlling the molten metal temperature from the furnace to the caster might require maintaining the minimum temperature of the molten metal to within the range of about 695°C to 750°C. The exemplary strip casting step 11 is performed in a manner that

substantially avoids formation of coarse primary Fe-bearing intermetallics or heavy bands of eutectic segregation. This requires, as a minimum, control of casting conditions such as, for example, gauge, speed, and tip position, in order to solidify the alloy without deforming the semi-solid metal in a way that would result in segregation of solute-rich liquid to near the mid-plane of the strip.

Continuing to refer to Figure 2, the next step of the exemplary manufacturing process includes cold rolling the cast strip to a first intermediate annealing gauge 12, in one or more passes. The thickness of this gauge is preferably between about 1-4mm. The next step is to apply a first intermediate anneal 13. The first intermediate anneal occurs for about 1-10 hours at a temperature preferably about 300-450°C, and more preferably for about 1-6 hours at a temperature of about 330-400°C.

In one embodiment, the strip is then cold rolled to a final intermediate anneal gauge 14, preferably about 0.05mm to 0.2mm, in several passes. A final intermediate anneal 15 is then applied, again for about 1-10 hours at a temperature preferably about 300-450°C, and more preferably for about 1-6 hours at a temperature of about 330-400°C. Finally, the alloy strip is cold rolled to a final gauge 16. The exemplary final cold rolling step uses a preferred reduction of about 15-50%, and more preferably about 15-35%. As shown, an optional final partial anneal 16A can be employed after the step of cold rolling to final gauge 16. This final partial anneal 16A preferably consists of heating the product for between about 1-12 hours at a temperature of about 150-240°C.

In addition to the steps of continuously strip casting 11, cold rolling to a first intermediate anneal gauge 12, applying a first intermediate anneal 13, cold rolling to a final intermediate anneal gauge 14 and applying a final intermediate anneal 15, alternative embodiments of the method of manufacture may optionally further include the additional steps of cold rolling to at least one additional intermediate anneal gauge 13A and at least one additional intermediate anneal 13B of the strip. If employed, these fabricating steps occur after the step of applying a first intermediate anneal 13 but before the step of cold rolling the strip to the final intermediate anneal gauge 14. A preferred embodiment employing such additional fabricating steps will include cold rolling the strip to a second intermediate anneal

gauge 13A, using a preferred reduction of at least about 70% after the first intermediate anneal 13, and applying a second intermediate anneal 13B for preferably about 1-10 hours at a temperature preferably about 300-450°C, and more preferably for between about 1-6 hours at a temperature of about 330-400°C. The second intermediate anneal is preferably followed by a cold reduction of at least about 70% to the final intermediate anneal gauge 14.

The unexpected, advantageous attributes of the present invention are substantiated, and may be further described and understood, by reference to the following example, which summarizes post-braze strength, thermal conductivity and corrosion characteristics of finstock manufactured in accordance with the present invention as compared to conventional finstock. The example is provided for illustrative purposes and is in no way limiting.

EXAMPLE

Three alloys were cast on a commercial twin-roll caster. Casting conditions were carefully controlled to minimize the generation of coarse intermetallics or clusters of intermetallics in the form of center-line segregation, which can be detrimental to fabrication to light gauges. Molten metal temperature at the entry to the casting tip was maintained at or above 700°C throughout the cast. The alloys were cast as sheets with a thickness of about 7mm, and a width of about 1070mm. The sheets were cast at a rate of about 760mm/min.

The compositions of each of the three alloys are given, in weight-percent, in Table 1.

Table 1

Alloy	Si	Fe	Cu	Mn	Mg	Zn
1	0.82	2.1	0.02	0.65	0.01	0.74
2	0.96	2.2	0.02	0.65	0.01	0.77
3	0.96	2.2	0.02	0.66	0.10	0.77

Each of the three cast sheets were then processed to 0.05mm gauge finstock in a commercial aluminum sheet mill by the following fabrication process:

1) cold rolling in several passes from about 7mm to 1.8mm;
2) annealing for about 3 hrs at about 360°C;

3) cold rolling in several passes from 1.8mm to 0.062mm;

4) annealing for about 5 hrs at about 360°C; and

5) cold rolling to 0.05mm.

These materials were then subjected to two different brazing thermal cycles. One was a conventional-type brazing cycle (referred to as cycle A). Cycle A involved a soak of about 4-1/4 minutes at a temperature above about 590°C with a peak metal temperature of about 595°C and a cooling rate of about 70°C/minute below about 500°C. The second brazing thermal cycle was a shorter brazing cycle, (referred to as cycle B). Cycle B had a soak of about 3 minutes at a temperature above about 590°C with a peak metal temperature of about 598°C and a cooling rate of about 190°C/minute below about 500°C.

The post-braze tensile strength, electrical conductivity and corrosion characteristics of the three materials were measured after both of these cycles. The tensile data was measured in the longitudinal direction using ASTM E345 Specimen type B. Electrical conductivity was calculated from a measurement of electrical resistivity using a potential drop technique commonly employed in the art. The corrosion potential measurements were made in accordance with ASTM G69. The self-corrosion measurements were done by measuring weight loss after one week of exposure in an ASTM B117 neutral salt spray cabinet. The results of each of these tests are reported in the Table 2.

Table 2

Alloy	**Braze Cycle**	**UTS**	**YS**	**E.C.**	**Grain size**	**Self-corrosion**	**Solution Pot.**
		MPa	MPa	% IACS	microns	mg/sq mm	mV vs. AgCl/Ag
1	Cycle A	130	58	51.2	~5,000	0.29	-829
	Cycle B	131	58	50.4	~5,000	0.32	-814
2	Cycle A	140	60	51.1	~5,000	0.27	-772
	Cycle B	143	60	50.2	~5,000	0.24	-768
3	Cycle A	144	60	50.4	~5,000	0.10	-773
	Cycle B	147	62	49.5	~4,000	0.13	-759

The post-braze conductivity for these materials is seen to be dependent upon the braze cycle employed and this is understood in terms of the cooling rate

from the braze temperature influencing the amount of elements retained in solid solution with higher cooling rates trapping more solute and decreasing conductivity. This data substantiates the fact that the finstock and method of manufacture discovered through the present invention, provides an improvement over conventional finstock material, such as, for example, an AA3003+1.4 Zn type finstock. For example, typical AA3003+1.4 Zn type finstock after braze thermal cycle A has about 128MPa UTS, about 52MPa YS but only has a conductivity of about 40%IACS. The self-corrosion rate of a typical 3003+1.4 Zn alloy is approximately the same as the alloys of the present invention, and the solution potential for a 3003+1.4 Zn fin is about -760mV. Moreover, the coarse grain size of the present invention alloys is desirable for resisting sagging of the fin during the brazing operation.

In summary, the experiment clearly shows that the method of manufacturing and the resultant finstock of the present invention, produces fins for brazed heat exchangers that exhibit an attractive combination of post-braze strength, thermal conductivity and corrosion resistance that compares very well relative to conventional 3003+Zn finstock.

While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details, in addition to those discussed above, could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangement disclosed are meant to be illustrative only, and not limiting as to the scope of the invention which is to be given the full breadth of the claims appended and any and all equivalents thereof.